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CORRECTION: In the January number, 1934, article "Two types of genetic control over the development of shape," by Edmund W. Sinnott and Samuel Kaiser, the cuts for Fig. 1 and Fig. 2, pp. 3 and 5, were transposed in printing.

Studies of the occurrence and transmission of virus diseases in the genus Abutilon

JOHN Y. KEUR

(WITH PLATES 1–4)

Abutilon striatum Dicks. clon Thompsonii Veitch and its related forms which have long been cultivated because of their attractive variegated foliage, present three problems of special interest in a study of virus diseases. These are: (1) the means and methods of the transmission of the virus causing this variegation, (2) the possible immunity of green branches appearing on variegated plants, and (3) the possible occurrence of various strains or types of the virus in this group of plants.

MEANS AND METHODS OF TRANSMISSION

Abutilon Thompsonii was first displayed in 1868 by Veitch and Sons, in England, and the next year, on the continent. It was soon propagated extensively because of its attractive foliage. In propagating it Lemoine (1869) found that the variegation could be transmitted to several of the green Abutilons by grafting. It is probable that many variegated clons of cultivated Abutilons existing at the present time originated by graft infection from the clon propagated from the first variegated *Abutilon Thompsonii* plant introduced by Veitch and Sons.

Morren (1869) also found that the variegation could be transmitted not only through a variegated scion but also when a variegated leaf with its petiole was used as a scion.

Lindemuth (1902) was the first to demonstrate the transfer of the Abutilon variegation by intergeneric grafts among certain members of the Malvaceae. He succeeded in transmitting the variegation of *Abutilon Thompsonii* to *Althaea officinalis* L., *Althaea rosea* Cav., *Althaea narbonensis*, *Kitaibelia vitifolia* Willd., *Lavatera arborea* L., *Malva mauritiana* Mill., *Malva verticillata* L., *Malvastrum capense* Grcke., *Anoda hastata* Cav., *Palava malvaefolia* Cav., and *Sida napaea* Cav.

Baur (1904 and 1906) tested transmission of the Abutilon variegation by means other than grafting. His injections and inoculations of sap from diseased plants under normal conditions or under pressure, however, did not produce any symptoms of the variegation in normal green plants. His work was repeated and confirmed by Hertzsch (1927) and up to the present

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time no means of transmission other than by grafting are known for this virus.

It has never been shown that insects first fed on diseased and then on healthy plants of the Malvaceae are able to transmit the virus which causes variegation. This, however, does not preclude the possibility of such transmission by native insects in tropical countries where many of these plants are indigenous, but no study regarding this matter appears to have been made. Green plants have never become variegated under greenhouse conditions, although "Gardener's Chronicle" (1869, p. 276) states: "*Abutilon striatum* occasionally throws out a variegated shoot without being grafted." This report has never been substantiated.

The transmission of variegation through the seed has never been definitely observed for any of the variegated Malvaceae by previous experimenters and hence the conclusion, that there is no transmission through seeds. Morren (1869), without mentioning specific cases, says merely, "Les graines des plantes panachées donnent—des plantes saines et normales." Baur (1906) states repeatedly that "Sämlinge bunter Pflänzen sind immer wieder rein grünblättrig." He mentions specifically obtaining none but green seedlings from 300 seeds of a variegated plant of the species *Kitaibelia vitifolia* and from 70 seeds of a variegated plant of *Abutilon indicum*. He believes that the quantity of the virus present in the seeds is too small to infect the embryo.

Lindemuth (1907), reports: "Alle Samenpflanzen der durch Transplantation mit *Abutilon Thompsonii* buntblättrig gewordenen Abutilonarten und- sorten haben rein grünblättrige Nachkommen ergeben." As examples, he reports seeds obtained from *Althaea rosea*, *Malvastrum capense*, *Abutilon Avicennae* Gaertn., *Abutilon megapotamicum* St. Hil., *Abutilon* var. Erfurter Glocke, *Kitaibelia vitifolia*, *Lavatera arborea*, *Anoda hastata*, all of which had become variegated through grafting with *Abutilon Thompsonii*. In no case does he give the exact number of seeds and seedlings obtained, merely referring to hundreds of seeds. Commercial seeds said to be of *Abutilon Thompsonii* which he bought produced only green seedlings. He also obtained seeds from *Abutilon megapotamicum* which produced twenty seedlings, three of which showed intensely variegated leaves. Two months later, two seedlings had lost this "variegation" completely; the third one remained variegated. It is not stated whether the seeds were obtained from a variegated or from a green plant. Lindemuth claims that the variegation in the seedlings originated without being grafted. This suggests the possibility of virus transmission through seeds.

Hertzsch (1927) obtained seeds from a severely infected plant of *Abutilon indicum* but only green seedlings grew from them. His explanation

is that the embryonic tissues are not enough differentiated to be infected by the virus.

Cook (1931) reports from the West Indies, that seeds procured from variegated plants of *Abutilon hirtum* Sweet have produced none but green seedlings.

Lindemuth definitely reports seed of variegated Abutilons, obtained in all cases by cross-pollination, as follows: (1) *A. Thompsonii*×*A.* var. Rêve d'Or, seeds produced only green seedlings; (2) *A.* var. Erfurter Glocke×*A. Darwinii* var. *tesselatum*, seeds produced only green seedlings with small laciniate leaves; (3) *A.* var. Cannell×*A. Thompsonii*, seeds produced some green seedlings and some with greenish-yellow spots and dots. All seedlings showed diversity of leaf shapes, resembling those of either parent or very irregular and laciniate; (4) *A. Darwinii* var. *tesselatum*×*A. Thompsonii*, seeds produced green and yellow-flecked laciniate leaved seedlings. Thus Lindemuth's seedlings possessed yellow-flecked leaves in some cases. He calls such variegation "falsche Panaschüre." Such seedlings were never proved to be truly virus infected in so far as the transmission of their "variegation" to susceptible green plants is concerned, because no grafting tests were reported.

Thus the evidence was interpreted to indicate that the variegation found among the several clons, varieties and species of *Abutilon* is not transmissible through the seed. Although some seedlings showed yellow flecks and spots, they were considered as being different from the truly variegated types.

MATERIALS USED

The types of plants used in these experiments are the following:

Abutilon striatum clon Thompsonii. Propagated from a cutting of the original stock obtained in 1914 by Dr. A. B. Stout from Mr. R. L. Lynch who was then Director of the Cambridge Botanical Gardens, Cambridge, England.

Abutilon megapotamicum variegatum. Characterized by semi-trailing habit, narrow leaves showing variegation in large blotches. One clon was obtained from the Central Park greenhouses; another clon from Mr. S. Untermyer's estate at Yonkers, New York.

Abutilon clon "Garden Stock." This clon was propagated by the New York Botanical Garden for outdoor bedding purposes and differs from the *Abutilon Thompsonii* clon in intensity of variegation (yellow and green variegation, rather than white, yellow and green variegation), and in leaf shape (more narrowly pointed lobes).

Abutilon clon "Eclipse" Hort. This clon is similar to *Abutilon mega-*

potamicum variegatum except for its more erect habit, slightly larger leaves and petal coloration. The petals are pale orange rather than lemon yellow and the flower is more open. Obtained from Vincent's Nurseries at White Marsh, Maryland. Originated probably as a seedling.

Abutilon clon "Mulleri" Hort. (or Milleri). Similar to *Abutilon* clon "Eclipse" except for irregularities in leaf shape (more laciniate). Also probably of seedling origin. Obtained from Mr. Baudish of Pleasantville, New York.

Abutilon clon hybridium. Maple shaped leaves, similar to those of *Abutilon Thompsonii*, but less pointed and more irregularly variegated (pale blotches and small spots). Obtained from horticultural plantings.

Abutilon Regnellii Miq. A green-leaved species grown from seed obtained from Brazil. Leaves entire, not maple-shaped. This species is very susceptible to transmission of the variegation by grafting, showing symptoms quickly and distinctly, and is therefore frequently used as an "indicator."

A green clon was obtained from a seedling of *Abutilon* grown by Professor Hugh Findlay. The leaves were deeply five-lobed resembling those of *Abutilon* clon "Garden Stock."

TESTS FOR TRANSMISSION OF VARIEGATION THROUGH SEED

In pollination experiments with the variegated clons studied, it was found that no seed is formed when these clons are self-, close-, or intraclon pollinated. The bell-shaped flowers sometimes show incomplete or partial dichogamy. The numerous stamens are united at the lower end of their filaments to form a tube inside of which the gynoecium is found. When some flowers are open, pollen is being shed from the topmost anthers, and the styles which are united below and free above are still within the staminal tube. The stigmas protrude, however, before all pollen has been shed, and in some instances the styles curve and twist so as to come in contact with the pollen-shedding anthers, effecting self-pollination. The failure to set seed to self- and close-pollination is due to self-incompatibility.

The green species *Abutilon Regnellii* forms seed readily to self-pollination, and it becomes readily and strongly variegated when grafted with variegated scions. Several plants of *Abutilon Regnellii* were made variegated through graft infection with each of the five variegated clons used in these experiments. Seeds formed readily on the stock plants, which in many instances showed infection to such an extent that even the sepals and seed capsules became variegated. The seeds, obtained after variega-

tion had become general in a plant, were sown and results of the germination are reported in the following table:—

TABLE 1

Seeds and seedlings obtained from graft infected Abutilon Regnellii stock

SCION ON A. REGNELLI	NUMBER OF SEEDS	NO. OF SEEDLINGS GROWN	SEEDLINGS SHOWING VARIEGATION AFTER SIX MONTHS
A. Thompsonii	328	275	0
A. megapot. var.	191	123	0
A. Eclipse	236	173	0
A. Mulleri	210	187	0
A. Gard. Stock	372	211	0
Totals	1337	969	0

In these cases no variegated seedlings were obtained.

All possible combinations of cross-pollinations were made between the variegated clons. In these cases the seedlings obtained had both parents variegated. The data for these seedlings are shown in table 2.

The following table indicates that out of a total of 3915 seeds only 2229 or 57% germinated and that of the 2229 seedlings, 349 show "apparent variegation" or mottling. In all but two instances such mottling appears in some of the seedlings obtained from each inter-clon pollination of the variegated *Abutilon* clons. This "variegation" is somewhat unlike that of either parent. The variegation of the seedlings is less pronounced than that of the parents. In the latter, the green areas of the leaf are in sharp contrast to the white or yellow variegated parts, while in the "variegated" seedlings, the green areas are only indistinctly contrasted with pale green or yellowish areas. In addition, the "variegation" of seedlings obtained from the same parents differs in degree, extent and general appearance. Occasionally some seedlings show normal green leaves and branches in addition to "variegated" leaves. Such seedlings may remain in this condition or the entire plant may become green leaved eventually. In no instance have green branches become "variegated"; but "variegated" branches have infrequently produced young green leaves. This occurred mostly where the "variegation" consisted of a pale green mottling, sometimes discernible only in diffused light. Similar results were described by Dr. A. B. Stout in a paper delivered at the meeting of the A.A.A.S. in Philadelphia (1926) but at that time no tests had been made to determine if such "variegation" could be transmitted.

Table 2 also indicates that with four exceptions the progeny contained some seedlings with irregular laciniate leaves, although the great majority of the seedlings had leaves resembling the parent plants in shape. Plants with such asymmetrical laciniate leaves are usually smaller than normal

seedlings. Occasionally such plants produce branches with regular, symmetrical leaves which tend to be more vigorous. In most cases such laciniate leaves show evidences of "variegation," although the laciniate char-

TABLE 2

Data for seeds and seedlings obtained from inter-clonal pollinations of variegated clons

	SEEDS		SEEDLINGS		
	TOTAL NUMBER	GERMINATED	GREEN	VARIEGATED	TOTAL LACINIATE
Abutilon striatum clon Thompsonii Seed Parent					
Selfed	0				
×*A. Eclipse*	207	112	97	15	11
×*A. Mulleri*	214	150	127	23	7
×*A. megapot. var.*	135	96	82	14	5
×*A.* Garden Stock	139	81	77	4	0
×*A. hybridium*	55	22	22	0	0
Abutilon clon Eclipse Seed Parent					
×*A. Thompsonii*	81	55	49	6	6
Selfed	0				
×*A. Mulleri*	255	124	106	18	16
×*A. megapot. var.*	335	216	177	39	10
×*A.* Garden Stock	208	103	97	6	2
Abutilon clon Mulleri Seed Parent					
×*A. Thompsonii*	247	159	114	45	29
×*A. Eclipse*	180	101	73	28	12
Selfed	0				
×*A. megapot. var.*	163	101	84	17	11
×*A.* Garden Stock	102	37	30	7	3
×*A. hybridium*	265	88	82	6	2
Abutilon megapotamicum variegatum Seed Parent					
×*A. Thompsonii*	143	98	84	14	5
×*A. Eclipse*	268	175	143	32	7
×*A. Mulleri*	213	158	121	37	12
Selfed	0				
×*A.* Garden Stock	0				
×*A. hybridium*	0				
Abutilon clon Garden Stock Seed Parent					
×*A. Thompsonii*	209	156	151	5	0
×*A. Eclipse*	172	88	73	15	7
×*A. Mulleri*	105	37	22	15	1
×*A. megapot. var.*	0				
Selfed	0				
×*A. hybridium*	0				
Abutilon hybridium Seed Parent					
×*A. Thompsonii*	12	5	5	0	0
×*A. Eclipse*	0				
×*A. Mulleri*	207	67	64	3	1
×*A. megapot. var.*	0				
×*A.* Garden Stock	0				
Selfed	0				
Totals	3915	2229	1880	349	147

acteristics themselves cannot be definitely attributed to action of the virus. Lesley (1928) observed similar leaf distortions in 4 per cent of the seedlings obtained by crossing two "healthy" tomato varieties.

When variegated scions such as *Abutilon Thompsonii* are grafted on the "variegated" seedlings, the contrast between the green and the yellow leaf parts of the latter is greatly intensified. This intensified variegation, but not the mottling, can be transmitted to susceptible green scions such as *Abutilon Regnellii*. The symptoms produced in the green scions are in no way different from those produced by grafting scions of *Abutilon Thompsonii* and others directly on *Abutilon Regnellii*.

To test the transmissibility of the laciniate condition and of the "variegation" shown by some of the seedlings, the latter were grafted on and with *Abutilon Regnellii*. In no instance were the laciniate characteristics transmitted to scion or stock of *Abutilon Regnellii* (see table 3). No transmission was noted in most other cases, even after a graft union of several years standing.

Evidence of transmission of the variegation through seed was first noted in the case of two seedlings obtained by crossing *Abutilon Mulleri* with *Abutilon Thompsonii*. Similar crossings were repeatedly made and a few additional "variegated" seedlings were again shown to be capable of transmitting their "variegation" to susceptible green Abutilons. The data are recorded in the following table.

TABLE 3

Data on seeds and seedlings of Abutilon clon Mulleri×Abutilon clon Thompsonii

SEEDS		SEEDLINGS			
TOTAL NUMBER	GERMINATED	GREEN	LACINIATE	VARIEGATED	VARIEGATION TRANSMISSIBLE
36	18	0	9	9	0
27	22	10	6	12	0
35	12	5	6	7	1
19	15	12	0	3	1
78	70	57	8	13	1
48	6	5	0	1	0
162	128	106	7	22	1
Totals 405	271	204	36	67	4

The 67 "variegated" seedlings were tested with scions of *Abutilon Regnellii* to determine the transmissibility of their "variegation." Of the 67 grafts that were made, 48 proved successful. In these tests only 4 seedlings were capable of infecting *Abutilon Regnellii*. One of these is shown in plate 2. The symptoms produced were milder and less pronounced than when any other variegated Abutilon was grafted either on *Abutilon Regnellii* or on the Abutilon seedling (green clon). From this evidence, it is

concluded that the virus producing variegation in *Abutilon* clon Mulleri and *Abutilon* clon Thompsonii is in a limited way transmissible to some of the seedlings obtained when they are crossed.

Seedlings were obtained from crosses between variegated and green Abutilon clons and the data for these are tabulated as follows:

TABLE 4

Data on seeds and seedlings obtained from inter-clon pollinations of green and variegated clons

	NUMBER OF SEEDS	SEEDLINGS GREEN	SEEDLINGS VARIEGATED	SEEDLINGS LACINIATE
Abutilon Seedling (green clon) Seed Parent				
Self-pollinated	0			
Close-pollinated	0			
Intra-clon pollinated	0			
×*A. Thompsonii*	111	62	2	2
×*A. Eclipse*	35	12	2	0
×*A. Mulleri*	101	22	11	10
×*A. megapot. var.*	16	10	0	0
×*A.* Garden Stock	44	30	1	0
×*A. hybridium*	504	185	3	0
Abutilon Seedling (green clon) Pollen Parent				
×*A. Thompsonii*	39	26	0	0
×*A. Eclipse*	48	29	2	0
×*A. Mulleri*	64	22	11	0
×*A. megapot. var.*	65	30	4	0
×*A.* Garden Stock	69	47	0	0
×*A. hybridium*	422	165	9	0

The above table shows that, for the offspring of variegated ×green Abutilons and of green×variegated ones, of a total of 685 seedlings only 45 showed "variegated" characteristics. When 31 of these 45 "variegated" seedlings were successfully grafted on and with *Abutilon Regnellii* in no case did transmission of "variegation" take place. The laciniate seedlings mentioned in tables 3 and 4 were incapable of transmitting this condition to normal green plants.

POSSIBLE RECOVERY AND IMMUNITY

The earlier investigators noted that Abutilon varieties show differences in resistance to infection by grafting. Some varieties showed no infection or they lost their infection soon after becoming variegated. The first case of this was reported by Morren (1869) for *Abutilon tonelianum* from Mexico, which showed only temporary transmission of the variegation after grafting. He did not state whether this loss of variegation indicated a recovery from the disease or whether it was due to shading or loss of variegated leaves. Nor did he further indicate whether or not this recovery made the plant immune to further graft tranmisssion experiments. If,

without any special treatment, this plant should have lost its variegation, then we would find here the first record of an Abutilon recovering from the virus.

Lindemuth (1872, 1878) claimed a similar recovery for *Abutilon arborum* Sweet, *Abutilon* var. *Martius*, *Abutilon Pattersoni*, and *Abutilon vitifolium* Presl. In these cases he noticed the appearance of flecks, either large and single, or in groups scattered throughout the leaves. As the leaves grew larger, the flecks often became rarer until sometimes they entirely disappeared. Lindemuth did not perform any experiments, however, to determine whether such recovery represented permanent immunity. When biennials and herbaceous perennials such as *Althaea rosea*, *Malva mauritiana*, *Malva verticillata*, *Lavatera arborea*, *Kitaibelia vitifolia*, *Sida napaea*, have once become infected through grafting with *Abutilon Thompsonii* they remain variegated even after a winter rest. *Althaea officinalis* is an exception to the above since it loses its acquired variegation during the winter. Such plants can be reinfected, however, hence they are not permanently immune. During his work with intergeneric grafts among the Malvaceae, Lindemuth found that various genera show different degrees of susceptibility to infection by grafting, as in the case of *Lavatera arborea*, *Sida Napaea* and *Althaea officinalis*. After grafting *Abutilon Thompsonii* on various members of these three genera, he observed that some plants of each genus showed no transmission. Such apparent immunity does not necessarily indicate absolute immunity, for the appearance of the first symptoms of variegation may be greatly retarded, due to slow and irregular spread of the virus through the plant depending upon age, health and vigor of plant and scion, perfection of graft union, and finally, length of period of observation. In some instances, as shown in this paper, more than one year elapsed, after grafting, before the first symptoms of variegation appeared.

Baur (1906) confirmed Lindemuth's findings with regard to recovery after winter rest and to varying susceptibility. He also demonstrated that variegated plants could be "cured" by removing all leaves and then placing plants in the dark, and also by removing several successive crops of variegated leaves. The resulting green plants were not immune but could be reinfected.

The most conspicuous recovery from variegation is seen when a green-leaved branch develops on a variegated plant. Concerning the appearance of such green branches, Baur states, "Es kommt vor, dass auf buntblätterigen Exemplaren einzele Zweige auftreten, die dauernd grün bleiben." He reported these in the case of *Abutilon Thompsonii*. Such a branch was propagated by cuttings and he claimed that the resulting clon was immune

to the mosaic, although ordinary *Abutilon striatum* plants are highly susceptible. When the "immune" individuals of this clon were grafted on other variegated Abutilons no transmission occurred. Baur also found, as had Lindemuth, that immune green clons of species usually susceptible were in existence. Such is the case with *Abutilon arboreum* Sweet. He demonstrated that such immune branches, while not showing any visible symptoms of the mosaic nevertheless allowed passage of the virus. *Abutilon indicum* Sweet became variegated after it had been grafted on an immune green branch of *Abutilon arboreum*, which in turn had been in graft union with *Abutilon Thompsonii*.

Price (1932) working with species of *Nicotiana* noted that plants infected with ring-spot virus produced healthy appearing leaves, resulting in complete recovery of the plants in most cases. If such plants were inoculated with ring-spot virus or grafted on or with diseased plants no symptoms of the disease were produced, indicating an acquired immunity. This immunity persisted when the plants were propagated as clons through three generations from cuttings. He found however that juice and scions obtained from all the recovered plants were highly infectious and capable of transmitting the ring-spot virus to healthy plants.

In the course of the present experiments, the observations made by Lindemuth and Baur with regard to the appearance of green branches on variegated Abutilon plants are confirmed. It was noted in the cultivation of *Abutilon megapotamicum variegatum* that entirely green leaves and even green branches are of frequent occurrence. (Plate 5) If green branches continue to be formed the entire plant may eventually become green. In the other variegated Abutilon clons used in these experiments, the appearance of green branches on individual plants was less frequent. Whenever such branches were propagated as clons the resulting plants remained green and never showed any evidence of spontaneous variegation. Efforts were made to determine the following points:

a. Whether the virus is entirely absent or only masked in the green branches appearing on variegated plants.

b. Whether the virus may be transmitted through such green branches to infect a susceptible scion grafted on them.

c. Whether stimulated flow of sap will cause appearance of the variegation in green branches of variegated plants.

d. Whether such green branches are actually immune.

Various methods of grafting were tried to test transmission. Whip grafting proved the most successful. Raffia was used in holding the scion to the stock and a paraffin coating applied over the raffia to prevent drying out. Scions used were two to three inches in length. Immediately after

grafting, plants were placed either under bell jars or in moist chambers (wooden framework with muslin covering kept moist). They were kept in these containers for two weeks or more, while light and air were admitted gradually, from day to day, until finally plants could be placed in a shaded part of greenhouse bench. The most successful grafts were made during the spring and the fall of each year. After a month or more the raffia binding was slit.

In testing for the possible presence of the virus in green branches of variegated plants, scions of such green branches were grafted on *Abutilon Regnellii* and on a green clon of an Abutilon seedling. At the same time reciprocal grafts were made by cutting off the tops of such green branches, and adding *Abutilon Regnellii* scions. The results of the experiments are tabulated in tables 5 and 6.

TABLE 5

Data on grafts made to indicate the presence or absence of the virus in green branches of variegated Abutilons

STOCK GREEN	SCIONS GREEN	GRAFTS	APPEARANCE OF VARIEGATION
A. Regnellii	*A. Thompsonii*	7	0
A. Regnellii	*A. Eclipse*	5	0
A. Regnellii	*A. Mulleri*	5	0
A. Regnellii	*A. megapot. var.*	6	0
A. Regnellii	*A.* Garden Stock	6	0
A. green seedling	*A. Thompsonii*	8	0
A. green seedling	*A. Eclipse*	5	0
A. green seedling	*A. Mulleri*	6	0
A. green seedling	*A. megapot. var.*	4	0
A. green seedling	*A.* Garden Stock	11	0

From the above, it appears that the virus is absent in green branches of variegated Abutilons for in no case did symptoms of the variegation appear in susceptible stock plants after grafting with green scions.

TABLE 6

Results of grafts to test the passage of the virus through green branches of variegated Abutilons

STOCK VARIEGATED WITH GREEN BRANCHES	SCION GRAFTED ON TOP OF GREEN BRANCHES	GRAFTS	APPEARANCE OF VARIEGATION
A. Thompsonii	*A. Regnellii*	4	0
A. Thompsonii	A. green seedling	5	0
A. Eclipse	*A. Regnellii*	3	0
A. Eclipse	A. green seedling	4	0
A. Mulleri	*A. Regnellii*	3	0
A. Mulleri	A. green seedling	3	0
A. megapot. var.	*A. Regnellii*	4	0
A. megapot. var.	A. green seedling	2	0
A. Garden Stock	*A. Regnellii*	5	0
A. Garden Stock	A. green seedling	3	0

The results reported in table 6 indicate that the virus does not pass through green branches present on variegated Abutilons in sufficient quantity to show symptoms of the variegation in susceptible green scions when these were grafted to the green branches. After the scions were successfully established, the variegated parts of the plants were trimmed down in the effort to stimulate flow of sap into the green branches. This, however, failed to produce any symptoms of the virus in the green scions.

To determine whether the green branches appearing on variegated plants are actually immune, the following test was made. Vigorous plants were obtained from cuttings of the green branches and then scions of variegated plants were grafted to them. The results are shown in table 7.

As shown in table 7, plants propagated from green branches of five different types of variegated clons were grafted with scions of all five types of variegation. None of the green plants thus tested was actually immune, since it could be reinfected. Such reinfection was accomplished not only by grafting on them variegated scions of other Abutilon clons, but also scions of their own variegated clon, (plate 1) providing plants and scions used were young, and not woody. When scions gradually became more woody it was noted that a longer time elapsed before symptoms indicating the transmission of the variegation appeared.

THE POSSIBLE OCCURRENCE OF STRAINS OR TYPES OF THE VIRUS

Hertzsch (1927) first recognized the existence of two different types of virus among variegated members of the Malvaceae. He named these types "A" and "B" chlorosis. As a basis of comparison, he uses the different symptoms produced by these types when grafted on identical plants. His "B" chlorosis produces more pronounced symptoms or a more intense variegation than the "A" type. He also finds that the species *Lavatera arborea* is immune to the "A" type and susceptible to "B."

In the course of the grafting experiments to determine immunities, it was noted that scions of different variegated clons may produce different symptoms when grafted on green plants of the same clon. Thus, when *Abutilon Thompsonii* and *Abutilon* Garden Stock are grafted on green *Abutilon Thompsonii* plants, different symptoms are produced. The variegation of *Abutilon Thompsonii* is much more intense than that of the clon Garden Stock. The same difference in intensity is evident in the transmitted symptoms when each is grafted on green plants of any of the five Abutilon clons used in these experiments.

When *Abutilon Thompsonii* is grafted on variegated plants of *Abutilon megapotamicum variegatum*, *Abutilon Eclipse*, and *Abutilon Mulleri*, no

TABLE 7

Results of grafts to test the possible immunity of green branches of variegated Abutilons

STOCK GREEN PLANTS	SCION VARIEGATED	GRAFTS	FIRST APPEARANCE OF VARIEGATION IN DAYS
A. Thompsonii	*A. Thompsonii*	2	30
		2	55
A. Thompsonii	*A. Eclipse*	1	70
		2	115
A. Thompsonii	*A. Mulleri*	2	55
		1	30
A. Thompsonii	*A. megapot. var.*	4	110
		1	370
A. Thompsonii	*A.* Gard. Stock	2	40
		2	60
A. Eclipse	*A. Thompsonii*	2	40
		1	40
A. Eclipse	*A. Eclipse*	2	60
		2	40
A. Eclipse	*A. Mulleri*	3	70
		1	50
A. Eclipse	*A. megapot. var.*	1	100
		3	90
A. Eclipse	*A.* Gard. Stock	1	50
		4	70
A. Mulleri	*A. Thompsonii*	2	35
		3	50
A. Mulleri	*A. Eclipse*	2	60
		3	85
A. Mulleri	*A. Mulleri*	2	65
		1	60
A. Mulleri	*A. megapot. var.*	1	105
		2	90
A. Mulleri	*A.* Gard. Stock	2	50
		4	85
A. megapot. var.	*A. Thompsonii*	2	50
		2	65
A. megapot. var.	*A. Eclipse*	1	70
		2	50
A. megapot. var.	*A. Mulleri*	2	90
		1	80
A. megapot. var.	*A. megapot. var.*	5	90
		2	110
A. megapot. var.	*A.* Gard. Stock	2	80
		1	90
A. Gard. Stock	*A. Thompsonii*	4	60
		2	85
A. Gard. Stock	*A. Eclipse*	4	90
		2	75
A. Gard. Stock	*A. Mulleri*	2	85
		1	60
A. Gard. Stock	*A. megapot. var.*	1	100
		2	130
A. Gard. Stock	*A.* Gard Stock	2	35
		4	50

change in character or degree of the variegation is noticeable in either scion or stock. But when an *Abutilon Thompsonii* scion is grafted on a normally variegated *Abutilon* Garden Stock, the variegation of the latter becomes greatly intensified; white and green instead of the usual yellow and green. Results of the above mentioned grafts are shown in plates 3 and 4.

It is evident from the above, that the type of virus present in *Abutilon* Garden Stock differs from that in *Abutilon Thompsonii*, as shown by symptoms produced in the same susceptible stock and that *A. Eclipse*, *A. Mulleri* and *A. megapotamicum variegatum* possess the same type of virus as *A. Thompsonii*.

DISCUSSION AND SUMMARY

The transmission of the virus. In no instance during these studies on the transmission of the virus among Abutilons did the variegation appear in normally green plants without being grafted. Hence the insects which were present in the greenhouses of the New York Botanical Garden did not transmit the virus to healthy green plants during the period when these experiments were conducted. This does not exclude the possibility of the existence of insect vectors where Abutilons are indigenous.

When variegated scions were grafted on green plants of the various Abutilons tested and vice versa, transmission occurred in all cases. No immune clons were found although differences in susceptibility were noted. Young variegated plants transmitted the variegation more quickly and readily to young green scions than did older ones. When older plants were used symptoms of the virus appeared after a greater lapse of time, creating the impression at first that the green stock or scion, as the case may have been, was immune, but in all instances the variegation did eventually appear.

The delay in the transmission of the virus is evidently due to poor contact of phloem in the area of the union of scion and stock. It was demmonstrated by Baur (1906b) that the transmission of this virus and the development of the variegation of Abutilons can be prevented by ringing the bark of susceptible green scions, showing that the causative agent is transported through the phloem tissues. When the ring is allowed to heal, transmission occurs. Hence to obtain ready transmission, it is necessary that phloem tissues of stock and scion establish contact.

The nature of green branches. The entirely green branches which frequently appear on plants otherwise strongly variegated are not immune to the virus. In the case of *Abutilon megapotamicum variegatum* the extension of the condition frequently results in entirely green plants. Baur

(1906a) claimed that such green branches are immune, but this was not confirmed in the case of green branches appearing on variegated plants of all the clons used in this study. These branches, propagated as green clons, could be reinfected not only by scions of the corresponding variegated clons, but also by scions of any of the other variegated clons.

Thus far, no such green branches have become variegated while attached to the original variegated plant, indicating that the condition which checks the flow of the virus to these branches remains permanent. The variegated parts of plants with green branches were trimmed down in the attempt to induce a flow of virus but in no case did the variegation appear in the green branches. That the virus is not present in green branches of variegated Abutilons is shown by the absence of infection when scions from such green branches are grafted on susceptible green Abutilon plants. In addition it was demonstrated that the virus does not pass through these branches on variegated plants to infect susceptible green scions. The appearance of green branches is then due to the arrested local distribution of the virus and is in accord with the evidence presented by Baur (1906b) that the virus is not systemic and does not exist in growing points but passes from older leaves to partly matured leaves in succession. Thus the growing points are already free of virus and in the appearance of green branches there is a failure in its flow into the young leaves at the time when they usually receive the virus.

Seed transmission. Definite evidence of the transmission of the virus through seeds was obtained. Of the 3185 seedlings grown which involve all possible combinations of inter-clon pollinations, 461 showed "variegated" characteristics. Of the seedlings tested 4 were capable of transmitting their variegation to *Abutilon Regnellii* and these seedlings were among those obtained from the crossing of *Abutilon* clon Mulleri with *Abutilon* clon Thompsonii, neither of which is self-compatible. Hence, the virus present in *Abutilon* clon Mulleri and *Abutilon* clon Thompsonii is transmitted to a small percentage of their offspring.

In addition to "variegated" characteristics some seedlings obtained from inter-clon crossings showed laciniate and distorted leaves. This characteristic was never transmitted by grafting to the normal green-leaved plants of *Abutilon Regnellii*.

Lindemuth (1878, 1907), Baur (1906a, 1906b), and Hertzsch (1927) reported that the seeds obtained from variegated plants produced none but green seedlings. This result was obtained in my experiments in the case of 969 seedlings grown from seeds of *Abutilon Regnellii* plants made variegated through graft infection. The apparent absence of the virus in the seeds of *Abutilon Regnellii* and the low percentage of infected seed-

lings from other plants indicate that the virus is not usually distributed to the embryo or, if so, that it does not retain its activity there.

Evidence of different strains of viruses. Concerning the existence of various strains or types of the virus in this group of variegated plants, Hertzsch (1927) reported an "A" and "B" type, especially demonstrated by the immunity of *Lavatera arborea* to the "A" type and not to the "B" type. In my studies the two distinct clons (a) *Abutilon* clon Thompsonii and (b) *Abutilon* clon Garden Stock are different in respect to the intensity of the variegation; the *Abutilon Thompsonii* being more intense. When *Abutilon Thompsonii* is used in grafts with *Abutilon* clon Garden Stock the variegation of the latter became intensified. When the two were grafted with plants of seven green stocks two distinct grades of variegation developed, as shown in plates 3 and 4. Thus the presence of two types of virus seems to be demonstrated. These results indicate the presence of two types of virus, but all clons tested were susceptible to both.

This research was carried on at The New York Botanical Garden, from 1928 to 1932 under the direction of Dr. A. B. Stout, and Dr. B. O. Dodge, to whom the writer expresses his sincere appreciation. He is also greatly indebted to Dorothy L. Keur for her able assistance in the preparation of the manuscript.

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Explanation of plates

Plate 1

A green branch of a variegated *Abutilon Thompsonii* was grafted (at A) on a plant of the same variegated clon. The scion grew and the variegation appeared in the young developing leaves of the scion after 172 days (B). This demonstrates that green branches appearing occasionally on variegated *Abutilon Thompsonii* plants are not permanently immune.

Plate 2

This seedling was obtained by crossing *Abutilon Thompsonii* with *Abutilon Mulleri*, both being intensely variegated. A single leaf of this seedling showing its variegation and laciniate characteristics is shown at A. A branch of a green *Abutilon Regnellii* was grafted on this seedling at B. After 37 days the variegation became evident in the newly developing leaves of this scion (C). Normal green leaves present at time of grafting or developing shortly after, are still present on the scion (D). Of all the "variegated" seedlings obtained from the above crossing, only four of those successfully tested were capable of transmitting their variegation to green *Abutilon Regnellii* scions. This demonstrates that the virus causing the variegation of *Abutilon Thompsonii* and *Abutilon Mulleri* is transmissible in a limited way to their seedling offspring.

Plate 3

Above. Effect of the virus of *Abutilon Thompsonii* in leaves of various clons of Abutilon. A. A leaf of *Abutilon Thompsonii* showing character of the variegation. B. A small branch of *Abutilon Regnellii* after graft infection by the *Abutilon Thompsonii* virus. Leaves are small, irregular and largely yellowish-white. C. The effect of the *Abutilon Thompsonii* virus on a leaf of a green *Abutilon megapotamicum* plant, showing large yellowish-white blotches against a green background. Plate 4 shows the characteristics of the variegated *Abutilon megapotamicum variegatum* leaves, very similar to the one pictured here. D. A leaf which developed on a green *Abutilon Eclipse* plant after graft infection by the *Abutilon Thompsonii* virus. The color is yellowish-white, with small green areas. E. A leaf from an originally green *Abutilon Mulleri* plant after graft infection by the *Abutilon Thompsonii* virus, showing yellow and green areas evenly distributed. F. The effect of the *Abutilon Thompsonii* virus on a green plant of *Abutilon* Garden Stock as shown by a typical leaf. G. A leaf of Professor H. Findlay's green Abutilon seedling, after graft infection by the *Abutilon Thompsonii* virus. H. A strongly variegated leaf from an originally green plant of *Abutilon Thompsonii* showing the most pronounced effect of the *Abutilon Thompsonii* virus.

Below. Effect of the virus of *Abutilon* Garden Stock in leaves of various clons of Abutilon. A. Leaf of *Abutilon* Garden Stock showing character of the variegation. B. The effect of the *Abutilon* Garden Stock virus after graft infection on a leaf of *Abutilon Regnellii* showing small yellow flecks and slight distortion. C. The effect on a leaf of an originally green plant of *Abutilon megapotamicum variegatum*. D. The same of *Abutilon Eclipse*. E. *Abutilon Mulleri*. F. A leaf which developed on a green *Abutilon Thompsonii* plant after graft infection by the *Abutilon* Garden Stock virus. G. A strongly variegated leaf from an originally green plant of *Abutilon* Garden Stock showing the most pronounced effect of the *Abutilon* Garden Stock virus. H. The effect on a leaf of Professor H. Findlay's green Abutilon seedling showing very slight variegation.

In comparing these two sets of photographs it is evident that when scions of *Abutilon Thompsonii* and *Abutilon* Garden Stock are grafted on the same series of green Abutilons, the effects produced by the *Abutilon* Garden Stock virus are much less distinct and pronounced than those of the *Abutilon Thompsonii* virus. This indicates the existence of at least two types of virus among the variegated Abutilons used in this work.

Plate 4

A plant of *Abutilon megapotamicum variegatum* on which *Abutilon Regnellii* was grafted (A), showing spread of the virus after 36 days. Green leaves present or just developing at time of grafting are still present (B). A green branch has developed on this plant (C).

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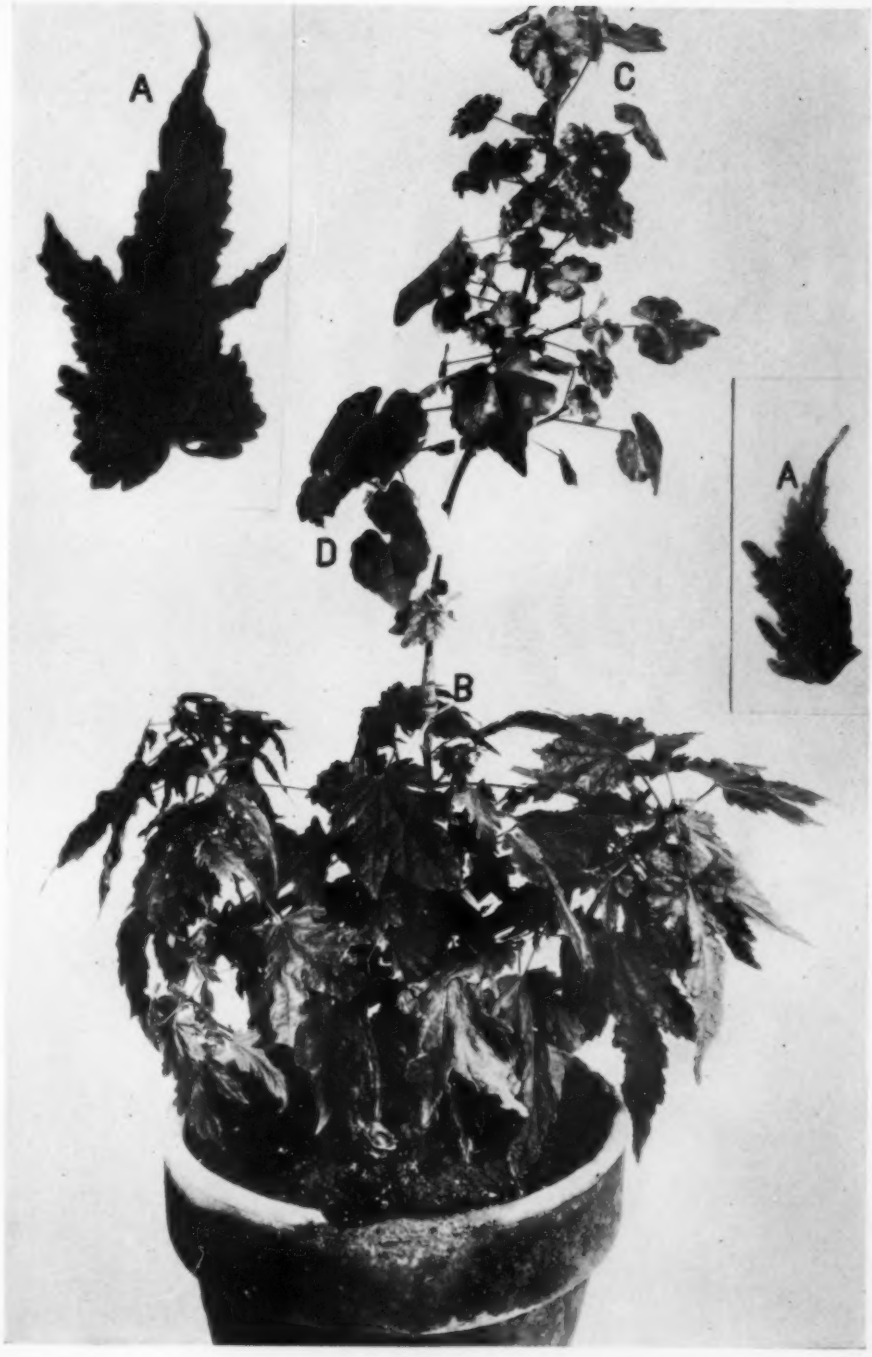

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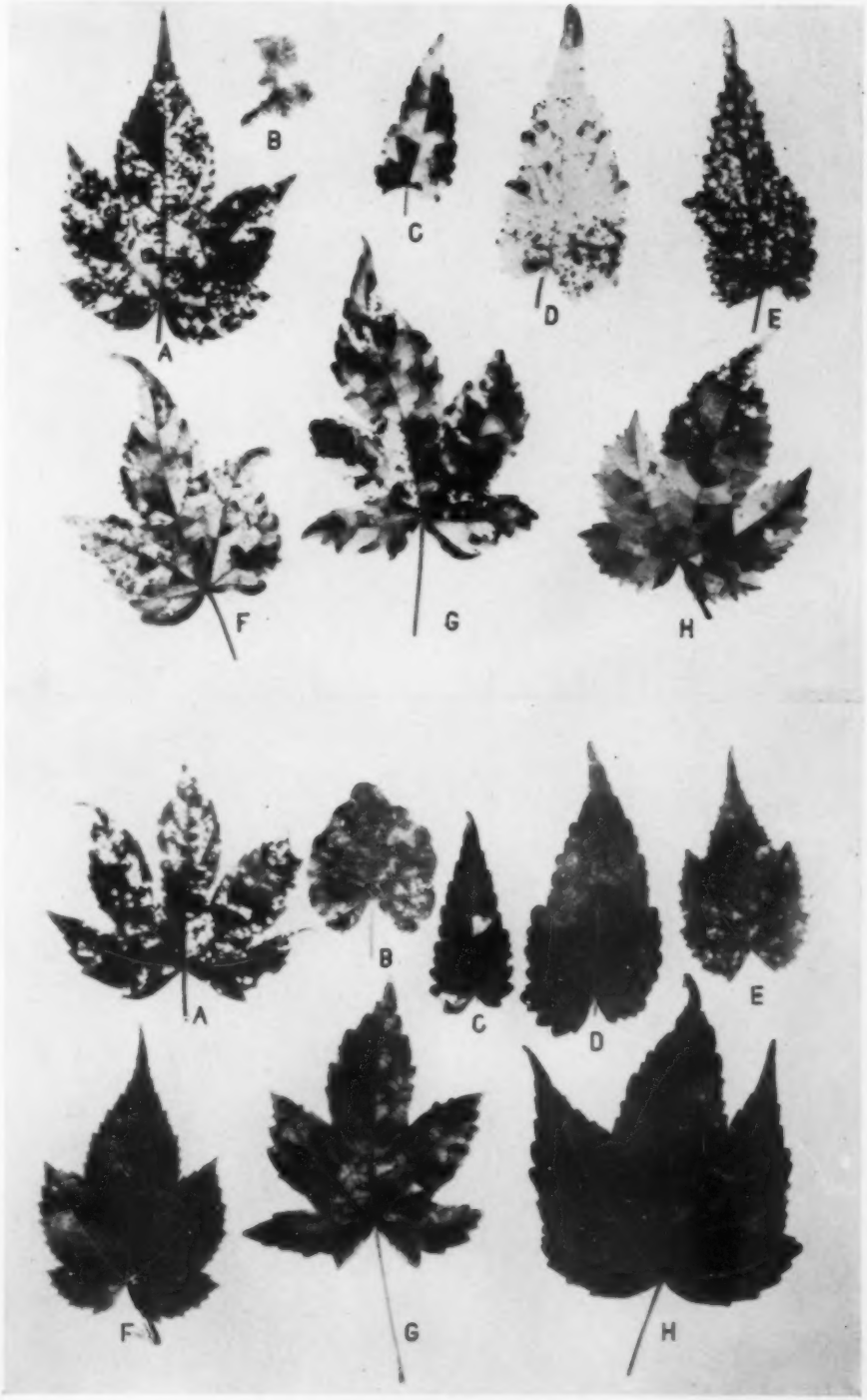

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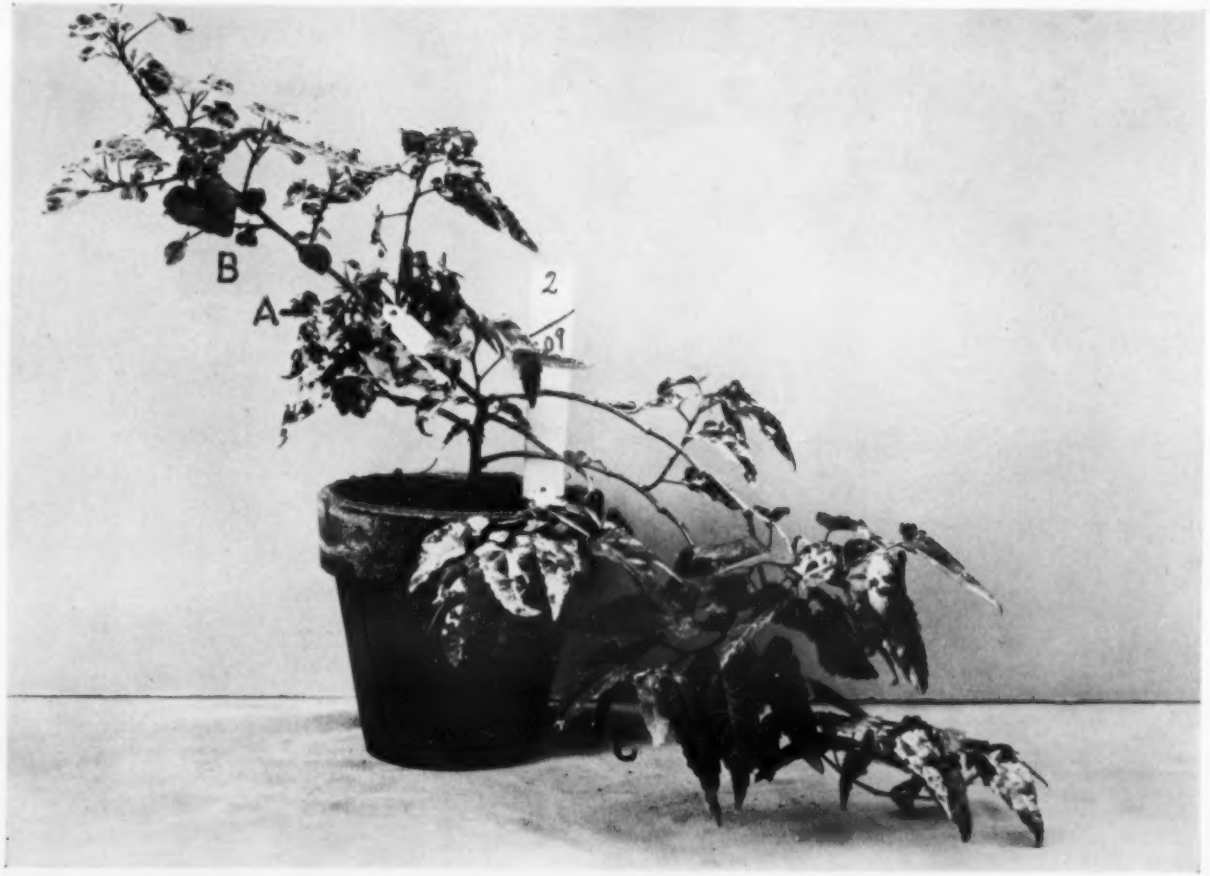

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The significance of the compiler's data in field work[1]

E. D. Merrill

All who have worked in any of the larger herbaria fully realize the shortcomings of our study collections when information beyond the mere Latin name and localization of a plant is being sought. In most cases the labels bear only the scientific name, the locality, the name of the collector, and the date.

Some years ago, in order to gain a definite idea of the amount of data usually compiled on herbarium sheets, I examined 3,000 specimens at random in three types of herbaria: one local, one economic, and one of exotic material, rich in original collections. In the local herbarium, only about 10% of the labels bore any information regarding the plants themselves; in the economic herbarium less than 3%; and in the exotic herbarium, where facts regarding the plants were especially essential to their understanding, only about 8%.

There is a vast field for improvement in modern herbaria, not so much in material already incorporated, but rather in future accessions. No one interested in economic botany could secure from any existing herbarium much information regarding the economic uses of plants. Neither could anyone interested in local names of plants secure many of these from actual herbarium labels, for the simple reason that collectors seldom record them.

A comparative philologist desiring plant names used by the more primitive peoples would find the average modern herbarium a barren waste. And in what place would he more logically seek such information? The monographer, having available great quantities of material from widespread sources, can frequently gain only the most sketchy ideas as to problems of environment, habitat, degree of abundance of any particular form, altitudinal ranges, soil preferences, and the like, except for the species growing in regions with which he is personally familiar through field work.

An individual working intensively on a definite area automatically assembles in his own mind vast stores of information regarding the plants with which he is familiar. Such information is not ordinarily compiled for incorporation in the herbarium, and his special knowledge usually dies with him. This is not the fault of the individual as much as it is the fault of the herbarium systems, the established methods of which have unfortunately perpetuated themselves.

[1] Presented in a Symposium on Objectives and Methods in Field Work, Systematic Section, Botanical Society of America, at Atlantic City on December 28, 1932.

That some labels carry information at all is an improvement over the earlier herbarium sheets, for at first the name of the plant was considered the only important thing. The locality and collector were sometimes written on the back. In more modern times, extensive bibliographic references are frequently supplied with *exsiccatae*, but the general information about the plant itself is as conspicuous by its absence as it is in the early basic historical collections.

Consider, for example, the problem of local names. In the eastern United States common names of plants are usually indicated in our manuals. Many of these are perpetuated by the manuals themselves rather than by the people who know the plants. Some never did have the sanction of popular usage; some are merely translations of the specific name or the binomial, and are therefore known only to the author and his readers.

On the other hand, as every country-bred individual who is interested in plant life knows, there are numerous local names of plants, sometimes widely used locally, that never appear in our manuals; they do not appear on our herbarium labels, and under our system or lack of system there is little chance that they ever will be so compiled. Is not a name in actual use for a particular species to be preferred to a coined name? And is it not worth while so to modify our field and herbarium methods that data of this type will actually be incorporated in the herbaria where they will be available for use?

I strongly suspect that the one factor that has inhibited the incorporation of field notes in the herbarium is the notebook system used by many collectors. The data are frequently compiled as notes, but this is as far as the information gets. On his return from a trip, or at the close of a season's field work, the average collector finds that he lacks the time necessary to transfer his notes *in toto* to his herbarium labels, so eventually the fate of his data is their preservation in greatly abbreviated form or their complete loss so far as concerns the individual specimens on which the notes were based. Never having been inoculated with the notebook germ, I have been in a position to consider a substitute system.

In 1899 I found that a field label of sorts was being used in at least one office of the United States Department of Agriculture. The curious thing here was that while these labels carried much detailed information, they were usually not associated with the herbarium sheets and very frequently only the most abbreviated notes were transferred to the herbarium label; the field labels were temporarily preserved in number sequence, but eventually most of them went into the waste-basket.

In some institutions where duplicate copies of field labels were supplied by me supplementing the conventional field label, I have observed

that these were actually discarded by the mounters, or if preserved were not attached to the sheets. Some curators apparently look on mounted herbarium specimens as art objects not to be disfigured by the addition of anything that will not go on a conventional label.

In 1902 I devised a distinctly crude label for use in the Philippines, where the services of individuals not trained in botany were being utilized for botanical exploration. Later in the year, while in Java, I became familiar with the field label developed by Doctor Koorders, and a slightly modified form of this was adapted to our Philippine needs. With the use of field labels a tremendous amount of information was compiled, and these original field notes were in all cases attached to the study-set in the Bureau of Science herbarium. Thus when actual plant work was commenced in preparing my "Enumeration of Philippine Flowering Plants," I actually had before me as I worked over the sheets all the data that were compiled in the field by the numerous collectors, covering habitats, altitudes, relative abundance, soil preferences, colors of flowers and fruits, and other information of this type that the dried specimen itself did not show, as well as local names and economic uses. Thus, of approximately 12,000 native plant names listed in that work, more than nine-tenths of them were taken directly from the herbarium sheets.

One striking thing about the field label is that rarely will a trained botanist adopt it voluntarily, especially if he be accustomed to the notebook system. I must confess that I did not use it consistently until some 8 to 10 years after all the foresters, rangers, and amateur botanists with whom I was in contact in the Philippines were consistently using it. I have been informed by the director of one of our most important institutions that he failed in his efforts to get botanists to use the field label, yet nonbotanists who collected for him used it freely.

The field label idea has been widely disseminated during the present century and various forms are now utilized by botanists and collectors in many parts of the world, particularly in China, Japan, Malaysia, the Philippines, and Australia. Comprehensive collections assembled when these simple forms have been consistently used are of much greater value for study and reference purposes than are collections without such data, because the botanist having access to the original study-set has before him instead of merely abbreviated notes or no notes at all, a complete file of all observations actually recorded by the collector in the field. In herbarium practice the field labels are attached to the upper left-hand corner of the herbarium sheets, supplementing the conventional label.

Field labels may be modified in an infinite number of ways and adapted to other uses than simply systematic botany. They may be simple or com-

plex, with few entries for the experienced botanist who knows what should be recorded; or more numerous ones to guide novices as to the types of data desirable for a record. In practice, notes can actually be compiled on field labels with greater rapidity than in a notebook; and where necessary or desirable, through the use of carbon paper, duplicates or triplicates can be prepared.

My special plea is for botanists and collectors to be open-minded enough to give the field label a fair trial. We find in practice that not infrequently these original field notes supply the clues to the actual segregation of species. They furthermore supply the botanist with many details regarding the plants themselves that would otherwise not be available to those who largely depend on standard herbarium specimens as a source for their information. One sometimes feels that the vast majority of botanical collectors, themselves very familiar with the plants they deal with, do not take into consideration the needs of their contemporaries and successors who have occasion to study their material. Their specimens are often merely "specimens," like postage stamps in an album, telling little or nothing about the plant preserved. Our needs will be better served by a more comprehensive idea as to what a "specimen" should include, particularly in regard to the supplying of practical information about each plant, to be kept in the form of notes actually associated with the mounted specimens.

THE NEW YORK BOTANICAL GARDEN

Aims and objectives of plant introduction of the U. S. Department of Agriculture[1]

KNOWLES A. RYERSON

The plant explorer who works for the Department of Agriculture must set out on his journeys with a rather different intent from that of the botanist who is interested primarily in adding to the store of knowledge of the world's flora. He must ask himself constantly not only what is this plant, but would it grow back home and if it did, of what use would it be and to whom; not merely is it new to science but is it new to cultivation? In short, he is never a follower of pure science, but is instead a representative in the field of applied science. To this he must add the accomplishments of a horticulturist and an agronomist for he must be a collector of living material and must be able to send his collection home alive, no matter how difficult the journey or how remote the situation.

This attitude brings about not only a different program but a different mass of results which at first may seem of lesser importance when considered critically. It is possible that in all the years of work of the Division, no more than twenty-five new species have been gathered in by explorers, but it is also true that the plants brought in have touched nearly every economic plant industry of the nation's agriculture.

In this governmental activity three general purposes are readily recognized; first, the introduction of entirely new crops; second, the introduction of additional new varieties of those crops which are already established; and third, the introduction of material for use in the improvement of plants cultivated in field, orchard and garden through breeding and selection.

The emphasis placed on each of these purposes naturally has varied with the development of the country. In the early years, as civilization progressed westward across the continent, unlimited land and a wide range of soil and climatic conditions promised an extremely varied agriculture. The introduction of new crop industries was essential.

With the stabilization of agricultural activities, desire for new or better varieties of crops already cultivated, as for example, better wheats, barleys and oats, became an important factor in plant exploration activities, while at the same time the search for entirely new crops continued. Through systematic exploration, activities of the world's important economic crops have been studied and most of them adaptable to our condi-

[1] Presented in a Symposium on Objectives and Methods in Field Work, Systematic Section, Botanical Society of America, at Atlantic City on December 28, 1932.

tions have been introduced either through governmental or private agencies. Today our problem presents another phase. The expansion of the area of staple crops is being checked; actual reduction is being sought. The American farmer is endeavoring to cut down his total acreage and to improve the efficiency of the acres he does cultivate. He must receive higher yields at lower cost of production for those crops which compete in the world markets; or, if possible, grow crops which are non-competitive. The many factors resulting in higher production at lower costs,—increasing yields through improved varieties and strains and reducing the high annual losses from plant diseases, insect pests and extremes of weather,—offer the plant breeder his opportunity.

The annual toll taken of American agriculture by plant diseases alone is rather staggering. Actual estimates in dollars and cents that are made from time to time are open to varied interpretation. If the losses due to the long list of diseases now damaging our field and orchard crops could be eliminated, the cost of production of these crops could be very materially reduced.

While certain groups of plant breeders are at work on the development of disease-resistant crop plants, others are engaged in breeding pest-resistant types, varieties giving higher yields, resistant to drouth, heat and cold, improved canning qualities, and varieties suited to short growing periods in northern states and short rest periods in southern states. These are but a few of the problems which are under way.

This rapid expansion of the field of plant breeding concerns our plant collector since it has brought with it urgent demands for the wild relatives of all the range of our economic crops from whatever portion of the globe they may be found. Plants that might seem poor when judged alone may be of vital importance now that characters, chromosomes and genes are more fully understood.

To get a more accurate picture of the requirements of breeders as they exist throughout the country, a survey was made several years ago of the most important needs of the workers on federal and state projects for foreign plant material and around these needs the exploration and introduction activities are being largely organized, as a glance at the following list of expeditions of the past few years will show:

Brandes expedition in 1928 to New Guinea for wild relatives of sugar cane for breeding mosaic-resistant types.

Beattie expedition in 1927–1930 to the Orient for blight-resistant types of chestnuts, both for new varieties and for breeding stock.

Dorsett-Morse expedition to the Orient from 1929–31 for soybeans and

other legumes; over 4,000 types of soybeans were received for trial and breeding.

Ryerson-Alderman-Leslie expedition in 1929 to northern Manitoba and Saskatchewan for hardy wild types of native fruits.

Westover-Whitehouse expedition in 1929 to Russia, Turkestan and Persia for wilt-resistant types of alfalfa.

Nixon expedition in 1929 to Iraq for rain-resistant dates.

Dickson expedition in 1930 to Russia for rust-resistant wheats and other cereals.

Ryerson-Westover expedition in 1930 to Spain and North Africa for wilt-resistant alfalfas, citrus and deciduous rootstocks.

Russell-Reddick-Erlanson-Souviron expedition in 1930 to Mexico for wild and cultivated tuber-bearing Solanums for breeding phytophthora, mosaic and other disease-resistant varieties of potato.

MacMillan-Erlanson expedition in 1931–32 to Peru, Bolivia and Chile for similar Solanum investigations.

In some of these expeditions the Department has had the cooperation of the experiment stations of Cornell, California, Wisconsin, Minnesota and the Dominion of Canada.

In addition to expeditions, an extensive range of materials is being introduced through purchase and exchange from all parts of the world.

While special emphasis is being placed on the introduction of material for the plant breeder, as indicated by these recent expeditions, active work is also being pursued in connection with possible new crops, especially those which do not compete with crops now being grown. These include plants producing rotenone, rubber and ephedrine.

The most extensive single introduction problem is that of range improvement. It affects all the western states. The introduction of grass, legume and browse plants to supplement valuable native species is now receiving attention. Closely related to this problem is the introduction of plants for erosion control and for fire-break purposes, if rather inflammable species can be found.

EXPLORATION FOR ORNAMENTAL PLANTS

In the realm of horticulture, the most rapidly expanding section is that of ornamental plants. Our country is just beginning to overtake the pioneer and homestead period in so far as home and town beautification are concerned. As a hobby, gardening is offering keen competition to golf, and women's garden clubs are more in evidence in many sections than are

those exclusively devoted to bridge. As a people, we are beginning to appreciate the fundamental satisfaction of gardening which the English learned long ago. Commercial floriculture and landscape gardening likewise are developing rapidly. Because of these stimuli, the demands from all quarters for new and interesting flowering and ornamental plants are insistent. In no other field of horticulture is there such an opportunity to introduce entirely new and unknown forms to this country or to serve the plant breeder in the creation of strains peculiarly suited to our various soils and climates. Exploration for flowering and ornamental plants, shrubs and trees, in so far as this country is concerned, is hardly begun, though in England for many years privately financed expeditions have been organized exclusively for ornamental plants, as witnessed by the many expeditions to China during the last quarter century from which have been brought back literally hundreds of rhododendrons, primulas, lilies and other bulbous plants, berberis, pyracanthas, cotoneasters, and bamboos new to cultivation. No governmental expedition with such an objective has been possible here as yet.

BOTANICAL AIDS TO EXPLORATION AND INTRODUCTION

A most cursory study of plant exploration activities reveals the inseparable relationship between them and botany in all its branches. This involves not only a knowledge of the foreign field but of our own conditions and it is to the ecologist and plant geographer that we turn first. The taxonomist is then called upon to furnish data on plants existing in the regions to be studied. The physiologist supplies the data that may determine the choice of the particular species that will solve the problem. And the taxonomist must review the work to prove its accuracy.

The building up of an herbarium as such has not been a primary objective of the plant exploration work of the Department, but as a necessary aid for identification and comparison, the collection and preparation of herbarium specimens is an important part of field expeditions. The specimens are filed with the National Herbarium in Washington, D. C. A special seed collection, in charge of a botanist especially skilled in the identification of plants by seed characters, has been built up over a long period of years. Extensive photographic studies are made in the field. At the introduction gardens permanent living plant collections of some of the more important new plants are maintained.

As has been pointed out, the objective of all introduction activities is to establish valuable new plants in American industries as soon and as effectively as possible. To this end the Department has the cooperation of workers of state experiment stations, botanical gardens, arboreta, private

research agencies, of certain of the commercial institutions, and of a limited number of specially qualified individuals. In the past the facilities of fairly large numbers of private individuals have been used for testing, but the results for the most part have been unsatisfactory.

This discussion has dealt primarily with introduction activities in this country. There is another side to it; it is an international cooperative enterprise in which streams of plant materials flow both ways. The Division of Foreign Plant Introduction serves to a great extent as a clearing house for the requests of foreign investigators for plant materials from this country; it assists research workers of federal and state institutions in sending material to foreign countries. It also endeavors to supply from different sources native American material for which foreign countries can not send their own explorers. Through this mutual exchange many valuable introductions have been made.

Division of Foreign Plant Introduction,
U. S. Department of Agriculture

The box huckleberry as an illustration of the need for field work[1]

EDGAR T. WHERRY

The plant here discussed is a low evergreen ground-covering shrub with leaves resembling those of the common box, but with the technical characters of the blueberry family (*Vacciniaceae*). Michaux, in his "Flora Boreali-Americana," named it *Vaccinium brachycerum*, and gave the locality as "Virginia circa Winchester," although the specimen in his herbarium is labelled "Warm Springs," perhaps referring to what is now known as Berkeley Springs, in West Virginia. It was again found by Matthias Kinn, about 1800, in the Greenbrier Valley, and by Pursh in 1805 near Sweet Springs.

Upon the death of these early collectors, the localities from which they had obtained the box huckleberry were lost to science, and for many years Asa Gray was unable to obtain material for study in connection with his monograph of the family. In 1845, however, a colony of it was discovered by Spencer F. Baird near New Bloomfield, Perry County, Pennsylvania, enabling Gray to prepare an adequate description of the species and to refer it to the correct genus, its name becoming *Gaylussacia brachycera*. The friendship which sprang up between Gray and Baird ultimately led to the latter's becoming Secretary of the Smithsonian Institution, so this plant may be said to have played an important part in the development of science in America.

In 1918 Dr. Frederick V. Coville recognized that the isolated colony of the plant discovered by Baird consisted of a single individual, which had spread over 8 acres by means of rootstocks. As these grow on the average but 6 inches per year, the colony must have sprung from a seed which had germinated about 1200 years previously, and was thus to be numbered among the oldest of living things. Being nearly self-sterile, the seeds failed to produce young plants with sufficient vitality to reach maturity, and the species appeared to be in real danger of extermination through clearing of the land and vandalism on the part of the public.[2] If, however, another colony could be found and cross-pollination be carried out, vigorous seedlings might conceivably be obtained, permitting the introduction of the

[1] Presented in a Symposium on Objectives and Methods in Field Work, Systematic Section, Botanical Society of America, at Atlantic City on December 28, 1932. Contribution from the Botanical Laboratory and Morris Arboretum of the University of Pennsylvania.

[2] This area has subsequently been made a state preserve.

species into horticulture as well as into protected areas, and its consequent perpetuation. At that time, however, not a single other occurrence was known to any botanist consulted by Dr. Coville, nor was there any information in the literature which would lead to the finding of one. Had a list of American relic-endemics been compiled at that time, it would certainly have included the box huckleberry.

Fig. 1. Supposed distribution of *Gaylussacia brachycera* in 1918. 1. "Warm Springs," Michaux about 1790 = "Near Winchester," 1803; presumably Berkeley Springs, Morgan County, West Virginia. 2. "Krien Preyer," Kinn, 1800; = Greenbrier Valley, east of Lewisburg, Greenbrier County, West Virginia. 3. Sweet Springs, Pursh, 1805; in Monroe County, West Virginia. 4. New Bloomfield, Perry County, Pennsylvania, Baird, 1845. 5. Millsboro, Sussex County, Delaware, Commons, 1876. 6. Parksville, Polk County, Tennessee, Gattinger, 1901. All but No. 4 were lost to science in 1918.

A colony of the species had been found by A. Commons of Wilmington, Delaware, in the southern part of that state about 1875, and although it was reported to have been destroyed, the writer succeeded in rediscovering it in 1919. Cross-pollination between this and a clump from the Pennsylvania colony was carried out, and an article on the plant was published by Dr. Coville.[3]

Then one after another additional occurrences were brought to notice, —in Pennsylvania a few miles east of Baird's locality, in Maryland less than an hour's ride from Washington, in southwestern Virginia, and so on.

[3] Science, 50: 30. 1919.

In 1921 Rev. Fred W. Gray observed it near Dorr, West Virginia, and learning that it was locally known as "juniper-berry" and was used for food by the people of that region, he published in a local newspaper an inquiry as to where the plant so-named could be found. Notwithstanding the fact that the species had not been mentioned in any of the compilations dealing with the flora of the state, he received reports of over 75

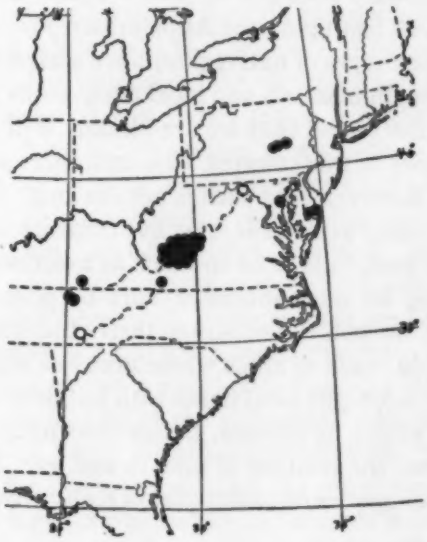

Fig. 2. Known distribution of *Gaylussacia brachycera* in 1932.

Pennsylvania: New Bloomfield; opposite Losh Run Station, also in Perry County, H. A. Ward, 1920; 15 miles northwest of Lebanon, Lebanon County, H. J. Roddy, 1930.

Delaware: Millsboro, rediscovered by the writer, 1919; west of Bethel, also in Sussex County, W. S. Taber, 1932.

Maryland: Pasadena, Anne Arundel County, C. C. Plitt, found about 1910 but not reported until 1920.

West Virginia: Michaux's locality never rediscovered; numerous localities found through efforts of Rev. Fred W. Gray, 1921, in Greenbrier, Mercer, Monroe, Pocahontas, and Summers counties.

Virginia: Several localities in Alleghany, Bath, and Craig counties, F. W. Gray; Fries Junction, Carroll County, W. K. La Bar, found about 1912, but not reported until 1919.

Kentucky: Just west of Cumberland Falls, Pennell and Wherry, 1927; two miles further west, Miss E. L. Braun, 1932, both in McCreary County.

Tennessee: Gattinger's locality never rediscovered; 3 miles east of Allardt, Fentress County, S. H. Essary, 1920; along White Oak River near Rugby, boundary between Fentress and Morgan counties, S. A. Cain, 1930; along Obed River near Rugby, Morgan County, Essary, 1931

stations distributed through five counties, and representing hundreds of acres of ground-cover.[4] Still later it turned out that in Kentucky the plant is called "ground-huckleberry" and in Tennessee "bear-huckleberry," and no doubt colonies additional to the few now known could be located in those states by similar inquiry under these names. Instead of being a relic-endemic, limited to one or two isolated colonies, as believed for a time, the species actually occurs in at least 7 states, from sea-level on the Coastal Plain to 3000 feet up on the Appalachian Plateau.

The fact that the ranges of native plants are stated with a considerable degree of definiteness in manuals and local floras tends to lead the student and amateur botanist to feel that we are already well informed as to the distribution of species in this country. Circumstances such as those above discussed indicate, however, that such is not the case. When a plant which forms a cover over many acres in at least five counties, and is known to natives as a source of food, fails to be so much as mentioned in a pretentious state flora, the need for more intensive work on plant geography is evident. Teachers will do well to encourage their students who are so fortunate as to live within reach of areas where man has not yet destroyed the native vegetation, to compile local floras with full field notes, including the names used for the plants by laymen. Before theorizing as to the principles of plant distribution, the relation of area to age, etc., let us first find out more as to where our species of native plants really grow.

DEPARTMENT OF BOTANY
UNIVERSITY OF PENNSYLVANIA

[4] Torreya 22: 17. 1922.

How field study can modify older taxonomic concepts[1]

F. W. Pennell

I suppose that many of us have pondered on the psychological behavior of successive generations of taxonomic botanists. We taxonomists are engaged in the fascinating task of trying to discover how the plant-life of the earth is interrelated and how its component divisions are distributed, assembling information that we deem fundamental to the study of plants from any other viewpoint. But the history of our science has not been a steady progress—it has shown rather a rhythmic course, now a period of rapid describing of new species, now a period of critical review in which the tendency has been to merge together what has already been described. In the slang of taxonomy, the rhythm has repeatedly swung from "splitting" to "lumping," and then from "lumping" to "splitting" again.

First there was necessarily a long period of exploration, during which new species were rapidly described. Perhaps some pre-Linnean author such as Bauhin first arrested this, but much more important was to be the effort of Linnaeus to put in order on a world-wide basis the information that had been acquired by the middle of the eighteenth century. In his "Genera Plantarum" Linnaeus based classification primarily upon the structure of the flower, and for this purpose, with his usual methodical thoroughness, he told for each genus whether he had studied it living, had seen it in the herbarium, or had merely adopted it from the account of others.

After Linnaeus came pure exploration again, and at an accelerated pace the multiplication of species. The world was wide, new floras were everywhere being discovered, and it was almost a logical conclusion that what appeared to be peculiar specimens would prove to be new species. From the days of the "Species Plantarum" nearly all study was made on dried specimens, for technique had improved while the collector usually had no time to do more than gather material for later inspection. The first flora of North America, the "Flora Boreali-Americana" of 1803, was based upon the specimens gathered during the extensive travels of the elder Michaux, but they were studied after his return to Paris and mostly by the French botanist Richard. Pursh, in his "Flora Americae Septentrionalis" of 1814, stated whether he had seen the species living, and he may well have made field descriptions. So may Thomas Nuttall for his "Genera of North American Plants" of 1818, and perhaps even that ardent field-explorer Rafinesque did so, although his work was too sketchy and impressionistic to gain much benefit therefrom.

[1] Presented in a Symposium on Objectives and Methods in Field Work, Systematic Section, Botanical Society of America, at Atlantic City on December 28, 1932.

But, just as a century before under Linnaeus, so toward the middle of the nineteenth century a vigorous reaction set in; Bentham, the younger Hooker, and Asa Gray (to mention botanists of the English-speaking world) attempted again to revise the immense accumulation of species descriptions, to eliminate duplications, and to get a better view of the taxonomy of the flowering plants. Hooker collected in Great Britain and in India, but his collections were studied as dried specimens at Kew Gardens. Species upon species he decided had been needlessly described, as what had seemed on a single or a few collections to be distinct entities had their supposed characters broken down by the inspection of more material. Finally, he was ready to exclaim: "More specimens always break down characters." In North America Asa Gray, working in the quiet of the Harvard Herbarium, felt equally confident in placing in synonymy hosts of the species of Nuttall, Buckley, and many others, as seeming intermediates appeared in the new collections that were every year flowing to his desk. Before leaving their company, may I say that for wide grasp of the taxonomy of flowering plants we have never had greater masters than Bentham, Hooker, and Gray.

Late in the nineteenth century came a reaction, this time away from the inclusive standards of these workers, and once more toward the rapid multiplication of descriptions of species. Exploration was still continuing, as indeed it had been under Gray, but now in our country instead of the opening west producing all the novelties, they were discerned in abundance in what had been thought to be well-worked fields. Much of the newer work was still wholly of herbarium material, and a multitude of species of Greene, Rydberg, and others, await future confirmation, but we must recall that it was Greene's field observations that led to a new understanding of *Antennaria* and Rydberg's to such evident distinctions as that of *Besseya* from *Synthyris*. Bicknell carried on the patient observations that showed us so clearly what species of *Sisyrinchium* and *Sanicula* grow in the northeastern states, and Fernald and Wiegand have by field study perfected our knowledge of many groups. The last are still aiding us, but the time draws near for another psychological reaction toward broad inclusive species, unless this newer work (and the conditions of life today) may have placed at our disposal new methods and criteria sufficient for a new kind of systematic study.

Leaving aside from this discussion such special themes as genetical and transplant tests, I want to ask what hope there is for practical taxonomy in field study. The herbarium botanist always wishes that he could actually see in all its details the living plant—it is obvious that any taxonomy would be greatly helped by descriptions of the plants as they grow

in nature. Again, the herbarium botanist, whether conservative or radical by temperament, is ever being puzzled by the odd or strange specimen —it would be of incalculable help if he could see the colonies whence such plants came so as to decide whether they were aberrant specimens or if they indicated some unsuspected distinct racial entity, species or subspecies. Lastly, if we can make the distinction between what are to be recognized as species or subspecies depend upon the presence of intergradation in nature, field study can give us invaluable help in judging such distinctions. I think that no brief is needed to plead the exceeding help of field study to taxonomy, but is such study on a wide scale practicable?

Over some of the world it already is so, and nowhere to such a degree as in temperate North America. The train, and more fully the automobile, have made possible a field taxonomy that may be either floristic or monographic. For the former look at Deam's work in Indiana, where one man, by means of the automobile, has raised his state from comparative neglect to that of the best known botanically in the Union. But I want to urge the prosecution of monographic work by field methods. After all it is easily possible for Mr. Deam, in spite of his thorough field study, to be mistakenly assuming that some Indiana species was the same as another species that was originally described from coastal Virginia, just as I shall soon show you how in all innocence botanists of Florida, of Texas, and of Missouri all had different species that they were all wrong in supposing was the Virginian *Penstemon hirsutus*. It is now possible for us to travel quickly over the entire ranges of many Nearctic genera, studying each species in flower and fruit, seeing its characters with new completeness, and learning its behavior and its distribution.

Species, when understood, tend to occupy definite and natural areas, and field taxonomy will contribute needed precision to our picture of North American biota. But for this purpose I would further urge the amplication of field knowledge by the study of the large amount of material that lies scattered in many herbaria of the United States. Recently, in studying the Scrophulariaceae of eastern temperate North America, I have been amazed to discover how much material is available in state and other local herbaria, and you will find the curators of these usually neglected collections only too glad to have their specimens critically studied. As the localities assembled from all sources are mapped, one may feel confidence in the validity of conclusions nearly in proportion as he finds each species coming to occupy a natural and logical range.

I might have chosen many examples of the modification by recent field study of the older specific concepts of Gray and his contemporaries. Occasionally the older species have failed to be sustained, but usually the

tendency has been to the recognition of finer and more precise entities, and I have selected as an example from the eastern United States what has become of the Grayan concept of *Penstemon pubescens*. From herbarium specimens, and those all too few, Gray quite naturally passed as one species, with range from Maine to Wisconsin, Missouri, Florida, and Texas, plants that as dried specimens seemed greatly alike, similar in capsules, sepals, leaves, and all marked by hairiness on the stem and leaves. But knowledge of the fresh corollas has shown contrasts so strong, that no one seeing them, would wish to hold together this old species; the distinctions of most importance concern corolla-form and color, but, from the clues so offered, one finds that there are also correlated characters of anthers, leaves, and hairiness. The group divides into thirteen taxonomic entities, all of which (because of lack of intergradation) I would prefer to consider species, though granting that a more conservative view could combine them into as few as ten species. Each of these thirteen occupies a definite and natural range.

A specimen, with map of all known counties of occurrence, was shown for each of the 13 species segregated from the former concept of "*Penstemon pubescens*"; these species are soon to be discussed, with reproduction of these maps, in the author's "Scrophulariaceae of Eastern Temperate North America" to appear from the Academy of Natural Sciences of Philadelphia.

Botanists, like other humanity, are subject to psychological laws, yet I think that field methods of systematic study can give criteria and the means of testing them that will greatly modify the next-recurrent swing of thought toward taxonomic conservatism. In the light of the evidence shown you, I challenge Hooker's dictum, for surely, on sufficient study, more specimens may as readily confirm suspected characters as break them down. If Hooker could have traveled over the area between India and Europe, or even into many consecutive valleys of the Himalayas, with time to have studied his species then and there, I wonder if he would not himself have changed what was an herbarium verdict.

We shall always need herbarium workers, for only by their trained skill in comparing plants will it ever be possible to study at all adequately the vast floras of the earth. But let us, with all respect to the masters who have been or who are still with us, recognize that herbarium taxonomy is in its essence tentative—it needs bit by bit to be restudied and reevaluated by knowledge of the living plants in nature.

ACADEMY OF NATURAL SCIENCE OF PHILADELPHIA

Field work with the cryptogams, its needs and methods[1]

O. E. Jennings

The non-vascular cryptogams are much less known to botanists than are pteridophytes and spermatophytes. For the latter, size and apparent abundance have insured early and extensive attention, and their study is considered fundamental in botanical courses. But the systematic botany of the so-called "lower plants" is considered as of a more advanced and specialized character, and for good reasons.

In the first place, there are as yet very few general manuals of the large groups of non-vascular cryptogams which apply to any large area of the country, such as is the case for the pteridophytes and spermatophytes with Gray's "Manual" or Britton & Brown's "Illustrated Flora." Such comprehensive manuals as we have for the lower plants are generally of rather limited systematic scope. Such are the works of Seaver, MacBride and others among the fungi; Wolle or Collins among the algae; Grout on mosses. Or else they are decidedly technical, such as Tuckerman for the lichens or Ellis & Everhart for the Pyrenomycetes, or Arthur for the rusts.

Another feature which has contributed to the more specialized character of the systematic botany of the non-vascular cryptogams, is that most of them are small or even microscopic, and special methods and often special apparatus are necessary in field-work, as is particularly the case with certain of the groups of fungi and algae.

Because of the lack of comprehensive manuals for the non-vascular cryptogams and the more advanced and technical training for their collection and study, the work has been largely left to specialists. Few institutions and few localities possess a requisite number of such specialists to represent the various groups. One institution will have a local herbarium rich, for instance, in fungi, or in some group of them, but poor in other groups. The distribution of exsiccatae sets of specimens in lichens, fungi, and bryophytes, has helped, but many know the difficulty in using exsiccatae specimens from distant states. How much more satisfactory would have been an authentic and comprehensive local herbarium with abundance of material!

It is too much to expect, that we may have in the immediate future well illustrated, comprehensive, and thorough manuals for fungi, algae, or bryophytes. There is not yet the abundance of material available on which to base such manuals.

[1] Presented in a Symposium on Objectives and Methods in Field Work, Systematic Section, Botanical Society of America, at Atlantic City on December 28, 1932.

We need (1) a much greater representation of localities in the collections of the lower plants, (2) a much greater number of workers in the various groups, and (3) comprehensive manuals of greater systematic scope and wide geographic range. To attain these three general objectives we should stress emphatically the value and the need of detailed and intensive work on the flora of restricted geographical regions. Even a state is generally too large for the best work.

In 1905 I began collecting, building up a herbarium, and studying the mosses of the western half of Pennsylvania, an area about 150 miles square. Many trips were made, all counties were visited, and special attention was paid to ecological habitats. Eight years later I published an illustrated manual of the mosses of the region, including 248 species. Many species, such as *Stereodon imponens* and *Dicranella heteromalla* were represented by dozens of specimens from various localities and collected during practically all months of the year. Other species were collected but once. Notwithstanding the thoroughness with which this work was done, there have since been recognized more than 20 species in the same area. I had missed 8% of the moss flora of the region. Instead of the 248 species included in my Manual, there are probably at least 300 species in the region. Even yet there are considerable numbers of the species which I can not recognize in the field. They must be taken "on suspicion" and studied later under the compound microscope. This makes it all the more imperative that most careful and concentrated work be done in the field when dealing with such groups of the plants. When one is looking for specimens of forest trees he is likely to overlook some of the smaller mosses or liverworts.

In the field of the bryophytes, we do not at the present time have local floras which represent intensive collecting and study from any considerable part of the total area of the United States. One of the most urgent needs in the systematic botany of our country now is a large number of workers scattered over various sections and working on the local flora of some particular group of the non-vascular cryptogams. This might be stated as the great objective in the systematic botany of these lower plants.

METHODS OF COLLECTION

Others on this program have called attention to the need of more exact data on the specimens. In the non-vascular cryptogams, the ecological habitat is often a great aid in establishing the identity of the specimen. Depending on the method of caring for the specimen in the field, care should be taken to insure completeness and exactness of the field-label.

Bryophytes. Mosses and liverworts are easily cared for in the field. Envelopes make satisfactory receptacles for them, and the data of col-

lection may be written on the envelope. The habitat, whether on soil, logs, living trunks, rocks, etc., and the kind of trunk or log or rock should be stated. A common fault is to gather mixed specimens when, with a little care, the same plant could be obtained in nearly unmixed specimens. The plants should be in fruit, if possible. Herein lies one of the advantages of local work, for nearly every month is the distinctive fruiting period of some one of the bryophytes. One should keep in mind the various kinds of habitats preferred by various kinds of bryophytes; ponds, streams, soil, rocks, living trunks of trees, and even different heights on the tree-trunks. Some species prefer knot holes, and, to secure a good representation of *Fissidens*, for instance, many stones in the brook will have to be turned over and scraped on the under side.

Lichens. Soil lichens, such as *Cladonia*, may be placed in boxes in the field. If moist, they may be placed in envelopes as are bryophytes. It is often of advantage when unpacking dry fruticose lichens to moisten them somewhat to avoid breakage. They relax and become pliable immediately. Foliose lichens, if dry and brittle, should also be moistened before placing in the paper pocket in the field. The crustose lichens will have to be broken or chiseled off with the thin surface layers of rock in which they occur. General collections of the average botanist have a very poor representation of the crustose rock lichens! It took a forenoon with a chisel and hammer to collect crustose lichens on a large granite boulder on the shore of a lake in northern Ontario. There were about 20 species, and I would have missed some had I not examined the rock under a lens. Reading glass, hammer, and chisel are needed for such plants.

Fungi. Parasitic fungi on leaves, stems, fruits, or twigs should be collected, together with the suitable part of the host, and placed usually in paper envelopes, taking care to include in the data the identity of the host. Saprophytic fungi, such as some Polyporaceae, should be accompanied by data as to habitat, such as the kind of wood. It is of advantage in connection with the determination of many fleshy fungi to know the habitat. Mushrooms require careful handling. The late Dr. Kellerman used a basket and brought mushrooms home in handmade paper cones rolled on the spot to suit the size of the specimen. Often by the time he reached home there was a spore-print in the cone to indicate spore color. Mushrooms require carefully recorded data, as many of the characteristics, such as colors, attachment of the gills, nature of the surface, and nature of the longitudinal section may be lost or difficult to determine after the specimens are dried. A good guide as to the data to be recorded for mushrooms is to be found in the publication on Michigan fungi by the late Dr. C. H. Kauffman. Unless they are poisoned, naphthelene or other such materials should

be packed with dried collections of fungi, as insects readily infest them. Small boxes, such as pill boxes, are desirable for small fungi, such as most of the Myxomycetes. Perhaps the best method of preserving them is to glue them to the inside of the cover of the box. This may be done before the specimens are dry.

Algae. Larger algae may be floated on paper and mounted like flowering plants. Smaller types, such as most of the inland green algae, should be preserved in bottles. For desmids and diatoms, microscopic mounts should be prepared. Specimens may be placed in a solution of about 2½% formalin (about 4–5% formaldehyde). Many of my earlier collections dried out and were lost, even when placed in small vaseline-coated glass-stoppered bottles. Small bottles of specimens should be placed in a larger jar filled with formalin solution to prevent loss by drying out. For smaller algae special methods must be used. Some of the material may be examined on the spot, with a field microscope so that scums may be skimmed off the surface of the water directly into a wide-mouthed bottle. Smaller forms may be strained out in a piece of fine-mesh cloth and then rinsed into the bottle. A small cloth may be placed in a funnel through which the water is strained and then the cloth itself be placed in the preserving solution. A pipette is useful for bringing up deposits or scums from the bottom of a pool. The potential flora of a pond may be studied by bringing debris or mud into the laboratory and studying and preserving the forms which develop.

It is obvious that no one should attempt to make a collection of all the major groups of plants from a locality on *one* trip, because of the special methods and equipment and kinds of observations necessary for the various groups. It is better to make several trips with the object of confining one's efforts to one group of plants on any particular trip, or to at least only a part of the whole flora.

In conclusion, it is highly desirable that emphasis be placed on intensive local studies and the building up of good herbaria with the aim to publish accurate and adequate local floras and manuals.

CARNEGIE MUSEUM, PITTSBURG, PENNSYLVANIA

INDEX TO AMERICAN BOTANICAL LITERATURE
1930–1933

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

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